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AUTHOR Padilla, Michael J.; And Others
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ABSTRACT

The objective of this project was to develop a valid and reliable multiple choice test of six basic science process skills for students in grades 4 to 8 (ages 8 to 14 years). Seven criteria were outlined for the test: an emphasis on the six most widely used science process skills (observation, inference, prediction, measurement, communication, and classification); a multiple choice, four-option format; an emphasis on use of pictures and drawings to clarify and enhance items; an average test readability below the fourth grade level; test length that permits completion within one class period (45 minutes or less); a wide range of difficulty of items addressing each process skill; and content-free items. The first version of the 36-item Test of Basic Process Skills in Science was validated and administered to 133 fourth-, sixth-, and eighth-grade students to establish test reliability and to compute item difficulty and discrimination indices to aid in test revision. A second version was then administered to 684 students. Results show this version to be a reliable and content-valid test appropriate for use with students in grades 4 through 8. In addition, the item difficulty and discrimination indices for this final version are reasonably good. (JN)

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THE DEVELOPMENT AND VALIDATION OF A TEST OF BASIC PROCESS SKILLS

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Michael J. Padilla
Linda Cronin
Meghan Twiest

Science Education Department
University of Georgia
Athens, GA 30602

Paper presented at the annual meeting of
The National Association for Research in Science Teaching
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The Development and Validation of a Test of Basic Process Skills

Purpose of Study

The objective of this project was to develop a valid and reliable multiple choice test of six basic science process skills appropriate for students in grades four to eight (ages 9 to 14).

Theoretical Framework

Beginning with the development of the scientific method in the early 1900's, science educators and scientists have stressed the importance of the set of skills scientists use to solve problems. At various times, these skills have been labeled as critical thinking, problem solving, scientific thinking and, most recently, as the science process skills.

While it is difficult to identify the precise genesis of the term, present day usage stems in large part from two sources. First, Jerome Bruner wrote The Process of Education (1961) in which he stressed the need for curricula which allow for "solving problems on one's own" and advocated devoting the first two years of school to exercises in manipulating, classifying and ordering objects. In short, Bruner saw "those processes as educational ends in themselves..." (Shulman & Tamir, 1973).

Secondly, the new elementary curriculum, Science - A Process Approach (SAPA) focused its entire program on skills that scientists use to solve problems. SAPA defined the process skills

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as a set of broadly transferable abilities, appropriate to many science disciplines and reflective of the true behavior of scientists. SAPA divided process skills into two types -- basic and integrated. The basic science processes are observing, classifying, communicating, measuring, using space/time relations, using numbers, inferring and predicting. These skills provide a foundation for learning the more complex integrated skills. The integrated science process skills are controlling variables, interpreting data, formulating hypotheses, defining operationally and experimenting.

SAPA fulfilled a need for standardization of terminology within science education by distilling a group of highly complex intellectual activities into a set of relatively well defined process skills. Other new curricula of the era quickly adopted the SAPA list of skills and definitions, including the Biological Sciences Curriculum Study and The Science Curriculum Improvement Study. This agreement on terminology allowed science educators to focus on developing and evaluating the effectiveness of curriculum materials for teaching these skills.

While the focus on science process skills in educational research has produced some consensus of terminology and many process skill oriented curricular efforts, the development of instruments for measuring these skills has lagged far behind. Many instruments have been constructed. Some have focused on measuring all science process skills. For example, Tannenbaum (1968) created the Test of Science Processes which measures both integrated and basic process skills. Others were created for use with teachers only. For example Ludeman (1974) created a test of

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process skills primarily for pre- and inservice teachers. Still others have attempted to measure a subset of the basic process skills. Molitor and George (1976) created a test of basic process skills which measures skills which they called inference and verification, for example. Recently several attempts have been made to measure the integrated process skills; e.g., Dillashaw and Okey (1980) created a valid and reliable test of these skills intended for use with students in middle and secondary schools.

Little work has been reported on the development of a test of basic process skills. A preliminary instrument was developed by SAPA to measure the eight basic science process skills (the six measured in this paper plus time/space relations and using numbers) taught in that program. This test was to be individually administered to children. Unfortunately, no funds for testing and validating this instrument were forthcoming and it remained in an experimental form (Doran, 1978). Isaacs recently (1984) reported work on a test of basic process skills. However, that test was aimed primarily at students in their first three years of schooling and did not test the same six process skills that were proposed for testing in this project. Her test was designed to measure skills such as problem solving, collecting, making judgements and others.

No instrument was found that measured the basic science process skills set out for this study. In light of the need to have a test which corresponds to the most commonly taught basic process skills, the investigators began to develop the Test of Basic Process Skills in Science (BAPS). The following criteria were outlined for the test:

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(1) An emphasis on the six most widely used basic science process skills, i.e. observation, inference, prediction, measurement, communication and classification;

(2) A multiple choice, four option, format;

(3) An emphasis on the use of pictures and drawings to clarify and enhance items;

(4) An average test readability below the fourth grade level;

(5) Test length that permits completion within one class period (45 minutes or less);

(6) A wide range of difficulty of items addressing each process skill, and;

(7) Content free test items.

Procedure

Objectives for each of the six basic process skills were written and refined (Figure 1). One objective for each process skill, except classification, proved sufficient. For classification, two objectives, one dealing with classifying and another dealing with seriating objects, were necessary. These objectives were reviewed by several experienced science educators and found to be valid representations of the intended skills.

At least eight multiple choice items were written for each skill. All items employed four alternatives. From this pool the six items judged to be the best measures of each skill were chosen for inclusion in the test.

Problem content was chosen so as to be appropriate for elementary and middle grade students. Each item was carefully analyzed to ensure that the item measured the appropriate process skill and not science content knowledge. Content topics included bones, phases of the moon, leaves, sea shells, plants,

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microorganisms and others. Two sample items from BAPS are contained in Figure 2.

All items were subjected to a readability analysis. The FOG index (Gunning, 1975) was used because it predicts the reading grade level necessary to read with 90 to 100% comprehension. On this scale an average index of 3.95 was obtained, indicating that most fourth grade students should have little problem reading and understanding the test.

Validity

The resulting 36 item test was submitted to a panel of four science educators with experience in both test construction and the basic science process skills. The intent of this review was to establish content validity, objectivity of the scoring key, and the overall clarity of the test items. The panel was given the set of objectives and a copy of the test. To determine content validity each member matched test items to the appropriate objective. The panel also completed the test so the scoring key could be verified. In addition, comments on item clarity were solicited to allow modification where necessary. Of a total of 144 responses (4 raters x 36 items), the experts agreed with the test developers on the assignment of test items to objectives 95% of the time. They agreed 98% of the time on the scoring of items. These results were taken as strong evidence of content validity and objectivity of scoring. Comments and suggestions from the panel were used to further refine several items.

Field Trial 1

One hundred and thirty three 4th, 6th and 8th grade students from the same school district were administered the BAPS test.

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Both the middle and elementary schools from which these students were drawn serve an urban population of approximately 50% minority students.

The purposes of this test administration were to establish test reliability and to compute item difficulty and discrimination indices to aid in further test revision. Scores ranged from 4 to 33 correct (X = 22.4, s.d. = 5.3). The overall reliability (KR-20) of BAPS was .78. Item difficulties ranged from .20 to .90., with an average value of .62. Point biserial correlations (discrimination indices) for 30 of 36 items were above .20, with an average value of .34. All incorrect alternatives had point biserial correlations in the zero or negative range.

These results indicate that most items were functioning well. Those with biserial correlations below .30 were reviewed and considered for possible revision. Eight items underwent minor revision before they were included in the final version of the test.

Field Test 2

Six hundred and eighty-four students in grades four through eight were administered this second version of BAPS. All of the subjects came from the same school district which has a mixture of suburban and rural students. About 10 to 15% of the students in the district were considered minority. The school district has had a good overall reputation and excellent scores on standardized statewide tests. Students had had no special training in the basic process skills prior to completing the test.

The purposes of this administration were to establish test reliabilty for the final version of BAPS and to compute test

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statistics that would provide feedback about individual items as well as the entire test.

Scores ranged from 8 to 36 correct, with a mean score of 27.08 (s.d.= 5.32). The overall test reliability was .82 (KR-20). Item difficulties ranged from .27 to .95 with an average of .75. Point biserial correlations (discrimination indices) for 33 of the 36 items were above .25, with an average value of .38. Almost all incorrect alternatives had point biserial correlations in the zero to negative range. All test questions, except one, seemed to be functioning correctly. Since the item discrimination and difficulty indices fell within the acceptable range for reliable tests (Payne, 1974), it was decided that no further test revision would take place. Test statistics for this version of the test are displayed in Table I.

For additional analyses the entire BAPS test was broken down into its six subtests, one for each of the skills tested. The mean scores for the total group, as well as each grade level, on each of the six subtests are contained in Table II. Generally, mean scores increased from grades four through seven and leveled off from grades seven to eight. Scores for the subtests showed observation, communication, classification and inferring to be the least difficult skills or items. The predicting and measuring subtest means indicated these two skills were more difficult.

Conclusions

The final version of BAPS was shown to be a reliable and content valid test of six basic science process skills appropriate for use with fourth through eighth graders. The item difficulty

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and discrimination indices reported for the final version of BAPS were reasonably good. Work on the test continues; for example, more validity data is needed, including factor analysis for construct validity, and correlations with interview tasks for criterion validity. These two measures would be necessary before BAPS could be considered a highly valid measure of basic process skill ability.

In addition, more work needs to be done with BAPS relative to students in earlier and later grades. Is it feasible to ask second and third graders to take BAPS considering the reading level of the test? Would ninth and tenth graders top out on the test? More research is necessary on these and other test related questions.

Educational Significance

One of the major problems hindering further research with the basic science process skills has been the lack of any valid and reliable instrument for measuring the skills among students in elementary and middle school grades. The development of the Basic Process Skills of Science Test fills this void. It is a sad commentary on the educational process that skills and concepts are often not well taught (if taught at all) until they are measured. Science Educators, curriculum leaders, and science teachers now have an instrument which can be used to measure basic process skill mastery. Perhaps this test can begin to coax classroom teachers to focus on these important, but often neglected, skills in their classrooms.

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In addition IAPS should prove useful to educational researchers. Certainly the definitive paper on the acquisition of basic process skills has yet to be written. More research effort needs to be devoted to these important skills as a group as well as to individual skills, such as inferring.

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Observation

Given an object, a picture or a description of an object, the student will be able to state (select) an appropriate observation using several senses (or vice versa).

Communication

The student will be able to use words or graphic symbols to describe an event, picture or an object (or vice versa).

Classification

The student will be able to classify or select the appropriate single or multistage scheme for a given set of objects.

The student will be able to serial order or select the appropriate serial arrangement of a given set of objects.

Measurement

The student will be able to measure or estimate a measurement of an object or a picture of an object using a given set of units.

Prediction

Given a set of data or a pattern of evidence, the student will be able to state (select) an appropriate prediction of a future event.

Inference

Given an observation of an event, students will be able to state or select an inference or explanation of that event based upon that observation.

Figure 1. BAPS Test Objectives.

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7. Rick and Carol collected a basket of shells. They wanted to sort the shells into 2 groups. What would be the best way to sort these?

A. By shape

B. By age

C. By the number of lines

D. By where they were found

Skill: Classification

8. Kelley was playing in the park. She spotted an animal in the bushes. Which sentence tells you the most about what the animal <u>looked like</u>?

A. It was brown and scared.

B. It was tired and cold.

C. It was small with four legs.

D. It looked like a mouse with a short tail.

Skill: Communication

9. Jim found this leaf on his way to school.

What is your <u>best guess</u> about what happened to the leaf?

A. It has a rough edge.

B. A bug was eating it.

C. It has a stem.

D. A boy picked it.

Skill: Inference

Figure 2. Sample test items from BAPS and the skill which each measures.

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TABLE I

Characteristics of BAPS

Skills Tested:	observation inference prediction measurement communication classification
Number of Items:	36 (6 per skill)
Response Format:	multiple choice
Recommended Grade Level:	4 - 8
Time to Complete Test:	45 minutes
Test Readability:	3.95
Discrimination Index (Average)	.38
Difficulty Index (Average)	.75
Reliability - Total Test: (KR-20)	.82
Standard Error of Measurement:	
- Total Test	2.47

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TABLE II

Means and Standard Deviations for BAPS by Grade and Subskill

Skill	Grade 5	6	7	8	Total
Observation	4.4(1.4	4.9(1.1)	4.9(1.0)	5.1(1.1)	4.8(1.2)
Commun.	4.1(1.5)	4.8(1.2)	5.0(1.0)	4.7(1.3)	4.7(1.3)
Classif.	4.1(1.3)	4.8(1.2)	5.0(1.1)	5.1(1.1)	4.7(1.2)
Measure.	3.3(1.3)	3.9(1.2)	4.1(1.2)	4.2(1.2)	3.8(1.3)
Predict.	3.9(1.4)	4.4(1.0)	4.5(1.0)	4.3(1.0)	4.3(1.1)
Inference	4.2(1.4)	4.8(1.1)	5.0(1.0)	4.9(1.2)	4.7(1.2)
Total All Skills	24.1(6.1)	27.2(4.5)	28.7(4.2)	28.3(5.1)	27.0(5.3)

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